The following list of formulae may be found useful :

Law of radioactive decay $N = N_0 e^{-kt}$

Half-life and decay constant $t_{\frac{1}{2}} = \dfrac{\ln 2}{k}$

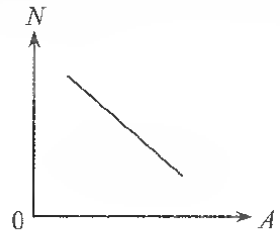
Activity and the number of undecayed nuclei $A = kN$

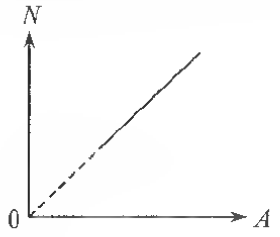
Part A :

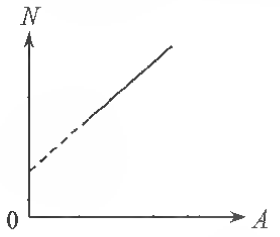
The following questions marked with { } are the past DSE questions.

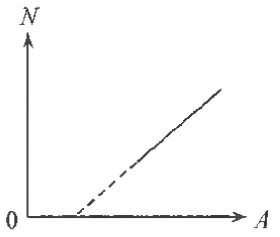
The number inside the brackets represents the year of the examination.

M1. {12} Isotopes of an element have different mass number A and neutron number N. Which of the following $N - A$ plots correctly shows the relationship of N and A for any given element ?

A.


B.


C.


D.


M2. {13} $^{238}_{92}U$ undergoes α - β - β - α decay and becomes a nuclide X. What are the atomic number and mass number of X ?

	atomic number	mass number
A.	90	230
B.	90	234
C.	88	230
D.	88	234

M3. {14} Nucleus W decays to nucleus Z as shown below :

$$W \xrightarrow{\alpha} X \xrightarrow{\beta} Y \xrightarrow{\beta} Z$$

Which of the following statements is/are correct ?

(1) Nucleus X has 1 more proton than nucleus Y.

(2) Nucleus W has 2 more neutrons than nucleus X.

(3) W and Z are isotopes of the same element.

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

M4. {15} A piece of ancient wood is dated using carbon-14 dating method. It registers a corrected count rate of 11.0 counts per minute while a fresh wood sample cut from the same kind of trees gives a corrected count rate of 15.6 counts per minute. What is the approximate age of the wood found in the archaeological site ? Given : half-life of carbon-14 is 5730 years.

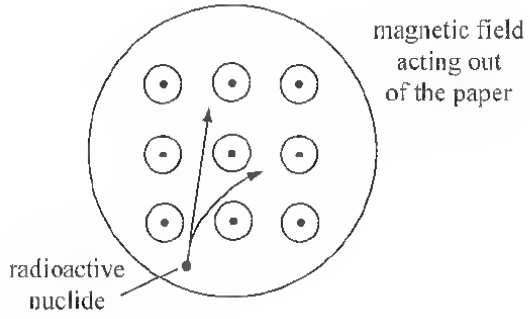
A. 890 years
B. 1300 years
C. 2000 years
D. 2900 years

Part B :

The following questions marked with ( ) are the past HKCE questions.

The number inside the brackets represents the year of the examination.

M5. (80) A radioactive nuclide ${}^{A}_{Z}X$ undergoes radioactive decay inside a cloud chamber. The radiations emitted are subjected to a magnetic field and the resulting tracks are as shown in the figure. What are the atomic number and the mass number of the remaining nuclide ?



	Atomic Number	Mass Number
A.	$Z-2$	$A-4$
B.	$Z+1$	$A-4$
C.	$Z+1$	A
D.	$Z-1$	$A-4$

M6. (80) The two isotopes ${}^{35}_{17}Cl$ and ${}^{37}_{17}Cl$ of chlorine have different

(1) numbers of protons
(2) number of neutrons
(3) chemical properties

A. (1) only
B. (2) only
C. (3) only
D. (1) & (2) only

M7. (81) Which of the following statements concerning isotopes of an element is/are correct ?

(1) They have the same number of neutrons.
(2) They have the same chemical and physical properties.
(3) They have the same atomic number but different mass numbers.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M8. (81) Which of the following represents an alpha decay ?

(1) ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th$
(2) ${}^{215}_{85}At \rightarrow {}^{211}_{83}Bi$
(3) ${}^{210}_{81}Tl \rightarrow {}^{210}_{82}Pb$

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M9. (83) The atomic structure of isotopes of the same element differ from each other by having different numbers of

A. electrons.
B. neutrons.
C. electrons and protons.
D. electrons and neutrons.

M10. An ancient piece of wood was tested for its age by carbon 14 dating method. The normal emission rate from 2 g of carbon
(84) from a living plant is 20 counts per minute. If the rate from 2 g of carbon from the wood is 5 counts per minute, and the half life of carbon 14 is 5700 years, what is the approximate age of the wood in years ? (Background radiation may be neglected.)

A. 5700×4
B. 5700×2
C. $5700 / 2$
D. $5700 / 4$

M11. During radioactive decay, ${}^{230}_{90}X$ becomes ${}^{226}_{90}Y$. Which of the following statements would be correct ?

(85) (1) The change would involve α decay only.
(2) One α particle and two β particles would be emitted.
(3) X and Y are two isotopes of the same element.

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

M12. A U-235 nucleus would change to Ac-227 through a series of decay :

(88) ${}^{235}_{92}\mathrm{U} \xrightarrow{X} {}^{231}_{90}\mathrm{Th} \xrightarrow{Y} {}^{231}_{91}\mathrm{Pa} \xrightarrow{Z} {}^{227}_{89}\mathrm{Ac}$

What kind of particles are emitted at stages X, Y and Z in the radioactive decay chain shown above ?

	X	Y	Z
A.	α	α	β
B.	β	α	β
C.	β	β	α
D.	α	β	α

M13. The atomic number of Tin is 50 and its mass number is 112. Which of the following is an isotope of Tin ?

(88) A. ${}^{112}_{51}\mathrm{X}$
B. ${}^{114}_{50}\mathrm{X}$
C. ${}^{112}_{49}\mathrm{X}$
D. ${}^{112}_{62}\mathrm{X}$

M14. ${}^{235}_{92}\mathrm{U}$ eventually decays to ${}^{207}_{82}\mathrm{Pb}$.

(89) What is the number of α particles and β particles emitted during the decay ?

	α	β
A.	7	4
B.	7	10
C.	14	10
D.	28	4

M15. If the nucleus of an atom is represented by the symbol ${}^{214}_{83}\mathrm{X}$, it means that this atom has

(90) (1) 131 protons in its nucleus.
(2) 83 electrons outside its nucleus.
(3) 214 neutrons in its nucleus.

A. (1) only
B. (2) only
C. (3) only
D. (1) & (2) only

M16. $^{238}_{92}U$ decays by emitting two α particles and two β particles. Which of the following represents the resulting nuclide ?

(92) A. $^{234}_{90}Th$

B. $^{234}_{92}U$

C. $^{232}_{88}Ra$

D. $^{230}_{90}Th$

M17. Which of the following symbols represents a neutron ?

(94) A $^{0}_{0}n$

B. $^{1}_{0}n$

C. $^{0}_{1}n$

D. $^{1}_{1}n$

M18. A radioactive nuclide *W* decays to a nuclide *Z* by emitting one α-particle and two β-particles as shown below.

(95) $W \xrightarrow{\beta} X \xrightarrow{\alpha} Y \xrightarrow{\beta} Z$

Which of the following statements about nuclides *W*, *X*, *Y* and *Z* is/are correct ?

(1) *W* and *Z* are isotopes.

(2) *X* has the greatest atomic number.

(3) *Y* has the greatest mass number.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M19. Which of the following is **not** an application of radioactivity ?

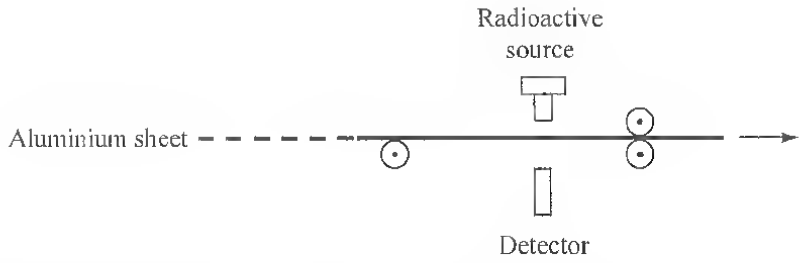
(97) A. Carbon-14 dating

B. Examination of foetuses (babies not yet born)

C. Killing cancer cells in human bodies

D. Sterilization of food

M20.
(98)



In a factory producing aluminium sheets of 1 mm thickness, a thickness gauge is used to monitor the thickness of aluminium sheets. Which of the following states the correct radioactive source to be used in the thickness gauge and the reason behind ?

	Source	Reason
A.	α	The amount of α particles passing through aluminium depends on its thickness.
B.	β	The amount of β particles passing through aluminium depends on its thickness.
C.	β	β particles are less harmful to human beings.
D.	γ	γ radiation has the greatest penetrating power.

M21. A nucleus X emits a beta particle to form a daughter nucleus Y. Which of the following statements is/are correct ?

(98)

(1) X and Y have the same number of neutrons.

(2) The number of protons in X is greater than that in Y by 1.

(3) The total numbers of neutrons and protons in X and Y are equal.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M22. Which of the following applications of radioactivity makes use of the fact that a radioactive nuclide has a constant half-life ?

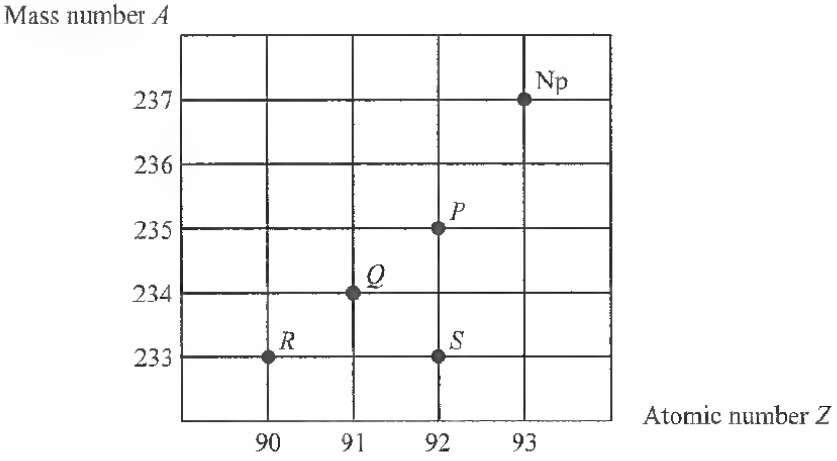
(99) A. Carbon-14 dating

B. Preservation of food

C. Smoke detectors

D. Thickness gauge

M23.
(99)



The above diagram shows the mass number A and atomic number Z of a few nuclides. The isotope of neptunium (Np) shown decays by emitting an α particle and then a β particle.

Which of the following represents the resulting nuclide ?

A. P
B. Q
C. R
D. S

M24. The below shows part of a radioactive series.
(01)

$$P \xrightarrow{\alpha} Q \xrightarrow{\beta} R \xrightarrow{\beta} S$$

Which of the following nuclei are isotopes of the same element ?

A. P and Q
B. P and R
C. P and S
D. Q and S

M25. Radium $\left({}^{226}_{88}\mathrm{Ra}\right)$ decays by emitting an α particle to form a product nucleus X. Which of the following shows the correct
(01) equation for this decay ?

A. ${}^{226}_{88}\mathrm{Ra} + \alpha \longrightarrow {}^{230}_{90}\mathrm{X}$

B. ${}^{226}_{88}\mathrm{Ra} \longrightarrow {}^{224}_{84}\mathrm{X} + \alpha$

C. ${}^{226}_{88}\mathrm{Ra} \longrightarrow {}^{222}_{86}\mathrm{X} + \alpha$

D. ${}^{226}_{88}\mathrm{Ra} \longrightarrow {}^{226}_{89}\mathrm{X} + \alpha$

M26. Which of the following is/are application(s) of radioactivity ?
(02) (1) to estimate the age of ancient remains
(2) to kill bacteria in food
(3) to transmit signals over long distances

A. (2) only
B. (3) only
C. (1) & (2) only
D. (1) & (3) only

M27. A radioactive isotope ${}^{234}_{90}\mathrm{Th}$ undergoes a series of decay processes to form a daughter ${}^{206}_{82}\mathrm{Pb}$. How many α-particles and
(02) β-particles have been emitted in this decay process ?

	No. of α-particles	No. of β-particles
A.	6	7
B.	7	6
C.	7	8
D.	8	7

M28. Which of the following are essential criteria in choosing radioactive sources as medical tracers in human bodies ?
(03) (1) The sources should have a short half-life.
(2) The radiation emitted should have a weak ionizing power.
(3) The radiation emitted should not be deflected by an electric field.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M29. In order to detect cracks in an underground oil pipe, an engineer proposes adding a radioactive source to the oil. Which of
(04) the following sources is most suitable ?

A. a γ source with a half-life of a few hours
B. a γ source with a half-life of several years
C. an α source with a half-life of a few hours
D. an α source with a half-life of several years

M30. A thorium nucleus (${}^{234}_{90}\mathrm{Th}$) decays by emitting a β particle to form a daughter nucleus X. Which of the following equations
(05) represents this decay ?

A. ${}^{234}_{90}\mathrm{Th} \longrightarrow {}^{230}_{88}X + \beta$

B. ${}^{234}_{90}\mathrm{Th} \longrightarrow {}^{234}_{89}X + \beta$

C. ${}^{234}_{90}\mathrm{Th} \longrightarrow {}^{233}_{90}X + \beta$

D. ${}^{234}_{90}\mathrm{Th} \longrightarrow {}^{234}_{91}X + \beta$

M31. (06)

$$X \xrightarrow{\alpha} Y \xrightarrow{\beta} Z$$

$$P \xrightarrow{\beta} Q \xrightarrow{\beta} R \xrightarrow{\alpha} S$$

In the above two decay series, P and Y are two isotopes. Which of the following pairs of nuclides are isotopes to each other ?

(1) X and R

(2) Y and S

(3) Z and Q

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M32. (06) Some fresh foods are exposed to γ radiations from radioactive isotopes for a short time so that the micro-organisms in the foods can be killed. Why are the irradiated foods not harmful to people who eat them ?

A. γ radiation is an electromagnetic wave.

B. γ radiation has a high penetrating power.

C. γ radiation does not have a high ionizing power.

D. γ radiation does not make the foods radioactive.

M33. (07) In the upper atmosphere, neutrons are produced by the action of cosmic rays. These neutrons interact with nitrogen nuclei as shown in the following reaction:

$$^{1}_{0}\mathrm{n} + {}^{14}_{7}\mathrm{N} \rightarrow X + {}^{1}_{1}\mathrm{H}$$

Element X will then emit a β particle.

The nuclear reaction is as follows : $X \rightarrow Y + {}^{0}_{-1}\beta$. What is the final product Y ?

A. $^{14}_{6}\mathrm{C}$

B. $^{13}_{6}\mathrm{C}$

C. $^{14}_{7}\mathrm{N}$

D. $^{13}_{7}\mathrm{N}$

M34. (09)

$$X \xrightarrow{\alpha} Y \xrightarrow{\beta} Z$$

The above shows part of a decay series. Which of the following deductions is/are correct ?

(1) X and Z are isotopes of the same element.

(2) X has two more neutrons than Z.

(3) Z has one more proton than Y.

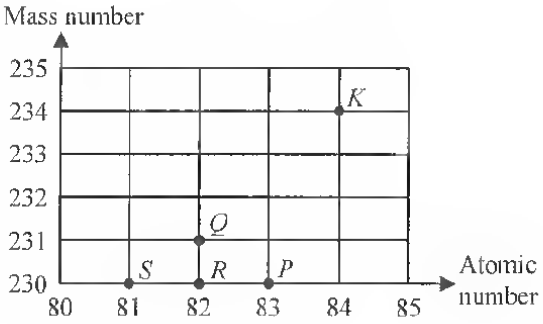
A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M35. (10) The diagram shows the mass number and atomic number of a radioactive nuclide K. After undergoing the following decays, it becomes Z.

$$K \xrightarrow{\alpha} X \xrightarrow{\beta} Y \xrightarrow{\gamma} Z$$

Which of the following nuclides represents Z ?

A. P
B. Q
C. R
D. S



M36. (11) A $^{238}_{92}$U nuclide undergoes a certain number of α and β decays and becomes $^{210}_{82}$Pb. Find the number of β particles emitted.

A. 2
B. 3
C. 4
D. 5

Part C :

The following questions marked with [ ] are the past HKAL questions.

The number inside the brackets represents the year of the examination.

M37. [81] A stationary radioactive nucleus of mass N units emits an alpha particle of mass 4 units, leaving a residual nucleus of mass $(N-4)$ units. The ratio of the kinetic energy of the alpha particle to the kinetic energy of the residual nucleus is

A. $(N-4)/4$
B. $N^2/(N-4)^2$
C. $(N-4)^2/N$
D. $(N-4)^2/4^2$

M38. [94] A stationary uranium-238 nucleus undergoes α-decay. What is the ratio of the kinetic energy of the daughter nucleus to that of the α-particle ?

A. 238 : 4
B. 4 : 238
C. 234 : 4
D. 4 : 234

M39. [95] $^{226}_{88}$Ra decays to $^{222}_{86}$Rn with a half-life of 1600 years. Which of the following statements is/are correct ?

(1) α particle is produced in the decay.
(2) All $^{226}_{88}$Ra has decayed after 3200 years.
(3) The half-life of $^{226}_{88}$Ra can be shortened by heating.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M40. [97] $^{226}_{88}$Ra is one of the nuclides in the uranium decay series. If the stable end-product of this series is $^{206}_{82}$Pb, the number of β-particles emitted between the $^{226}_{88}$Ra stage and the end of the series is

A. 4
B. 6
C. 10
D. 14

M41. [09] In β-decay a neutron inside the nucleus changes into a proton and an electron is emitted as a β-particle. Radioactive nuclide plutonium $^{244}_{94}$Pu becomes lead $^{208}_{82}$Pb after a series of α- and β-decays. Throughout the whole process, how many neutrons inside a $^{244}_{94}$Pu nucleus have undergone such change ?

A. 3
B. 6
C. 9
D. 12

Use the following data wherever necessary :

Avogadro constant $N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$

The following list of formulae may be found useful :

Law of radioactive decay $N = N_0 e^{-kt}$

Half-life and decay constant $t_{\frac{1}{2}} = \dfrac{\ln 2}{k}$

Activity and the number of undecayed nuclei $A = kN$

Part A :

The following question marked with { } is the past DSE question.

The number inside the bracket represents the year of the examination.

Q1. {13} Carbon-14 dating can be used to identify the age of some objects which have the ^{14}C isotope, as it is radioactive and decays by emitting a β-particle. A piece of wood sample is examined using carbon-14 dating and its activity is 0.2 Bq. The half-life of ^{14}C is 5730 years. Given : 1 year = 3.16×10^7 s

(a) Calculate the decay constant of ^{14}C in s^{-1}. Hence find the number of ^{14}C nuclei in this wood sample. (3 marks)

Assume that living organisms contain a constant proportion of carbon-14 in the ratio of ^{14}C / $^{12}C = 1.3 \times 10^{-12}$ during its life time via intake of carbon dioxide (CO_2) from the atmosphere.

(b) The carbon content of this wood sample is found to contain a total of 1×10^{23} carbon nuclei. Estimate the number of ^{14}C nuclei in the sample originally when it died. (1 mark)

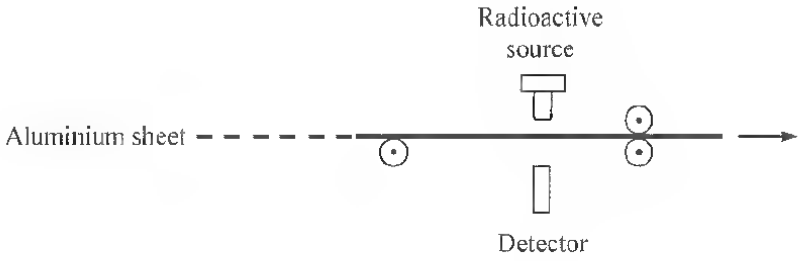
(c) Estimate the age of this wood sample in years using the results found in (a) and (b). (2 marks)

Part B :

The following questions marked with ( ) are the past HKCE questions.

The number inside the brackets represents the year of the examination.

Q2. (a) (80) A factory aims at producing aluminium sheets of 1 mm thickness. A radioactive source and a detector is used to monitor the thickness of the aluminium sheet manufactured as shown in the figure below.



(i) State what type of source (α, β or γ) should be used. (2 marks)

(ii) Explain briefly why the other two types of source are not used. (3 marks)

(b) Give TWO other applications of radioactivity. (2 marks)

Q3. (a) (81)

Figure 1

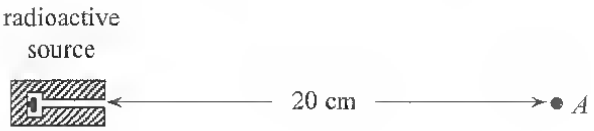
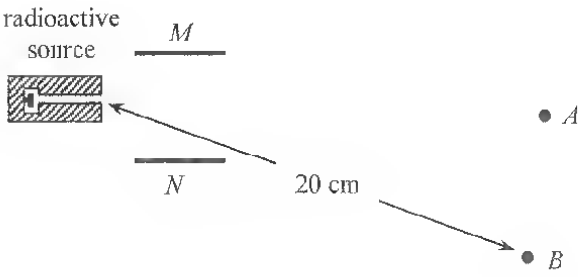


Figure 2



$^{238}_{92}U$ is a radioactive source giving α, β and γ radiations.

(i) If $^{238}_{92}U$ decays by emitting four α-particles and two β-particles, what will be the atomic number and mass number of the resulting nucleus ? (6 marks)

(ii) A GM counter is placed at *A* as shown in the Figure 1 about 20 cm from the source. What types of radiation can be received by the counter at *A* ? (2 marks)

(iii) An electric field is applied across the metal plates *M* and *N* as shown in the Figure 2 so that *M* is connected to the positive terminal and *N* is connected to the negative terminal of a voltage supply. The GM counter is now moved to *B* about 20 cm from the source. Describe and explain what happens to the count-rate. (2 marks)

(b) A small volume of solution containing a radioactive isotope with an activity of 4400 disintegrations per minute is now injected into the blood stream of a patient. After 20 hours the activity of 10 cm^3 of blood becomes 2 disintegrations per minute. If the half-life of the isotope is 10 hours, estimate the volume of blood inside the person. (5 marks)

(c) If an α-particle is emitted from an atom of $^{224}_{88}Ra$ during the decay process, what will be the mass number and the atomic number of the daughter atom ? (2 marks)

Q4. (a) What are the mass numbers of

(82) (i) α-particles,

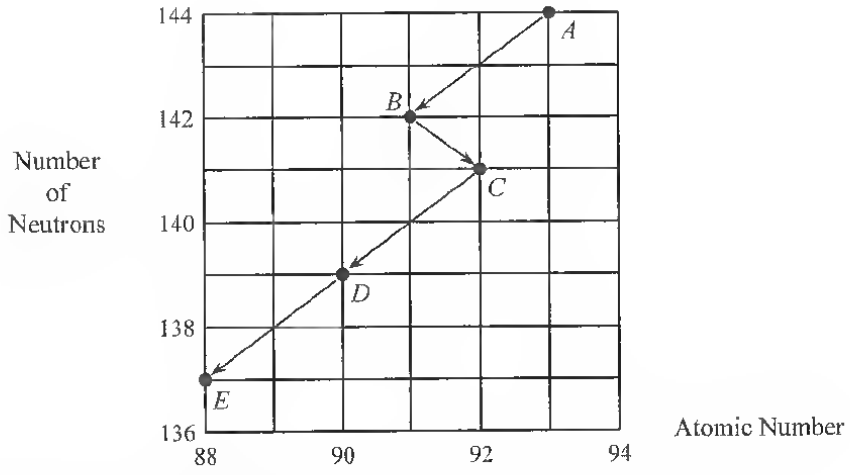
(ii) β-particles, and

(iii) neutrons ? (3 marks)

(b) The parent α source is $^{226}_{88}\text{Ra}$. If the daughter nucleus of Ra after α decay is X, write down the equation of the α-decay. (3 marks)

(c) If $^{234}_{91}X$ decays by emitting one α particle and one β particle to form a stable product nucleus Y, what will be the atomic number and mass number of Y ? (2 marks)

(d)

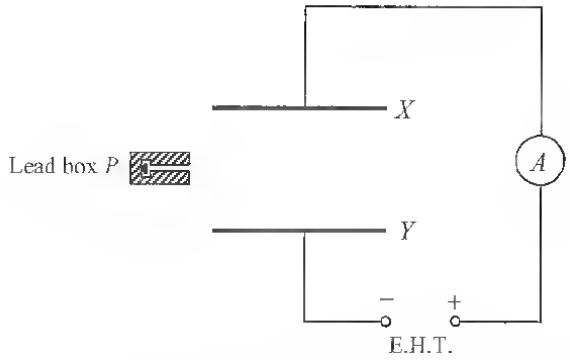


The above figure shows a radioactive decay series : $A \rightarrow B \rightarrow C \rightarrow D \rightarrow E$

(i) State what particles are emitted at each stage. (4 marks)

(ii) What is the mass number of C ? (1 mark)

Q5. (a) (91) Two metal plates X and Y are connected to a sensitive ammeter and an extra high tension supply (E.H.T.). A lead box P is placed near the metal plates as shown in the below figure.



(i) Sketch the electric field pattern between X and Y. The direction of the field should be shown. (2 marks)

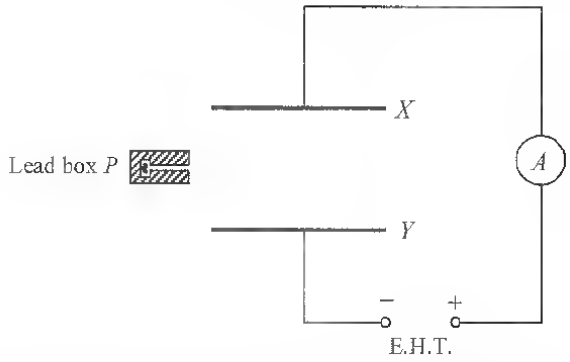
(ii) If a radioactive source emitting α particles is placed in P, the ammeter shows that a current is flowing. Explain why there is a current. (2 marks)

(iii) Explain what happens to the ammeter reading if the source in (ii) is replaced by one emitting γ rays ? (2 marks)

(iv) Suppose now a radioactive source $^{234}_{91}\text{Pa}$ is placed in P. $^{234}_{91}\text{Pa}$ decays by emitting a β particles and γ rays to form a daughter nucleus U.

(1) Write down an equation for the decay. (1 mark)

(2) On the below figure, sketch and label the paths of the radiation emitted by the source. (2 marks)



(b) Leaks in underground oil pipes can be detected by adding a small amount of radioactive source into the oil being pumped. Oil flows out from the leaks and radioactivity is detected on the ground around the leaks.

(i) Which type of source (α, β or γ) is suitable ? Explain briefly. (2 marks)

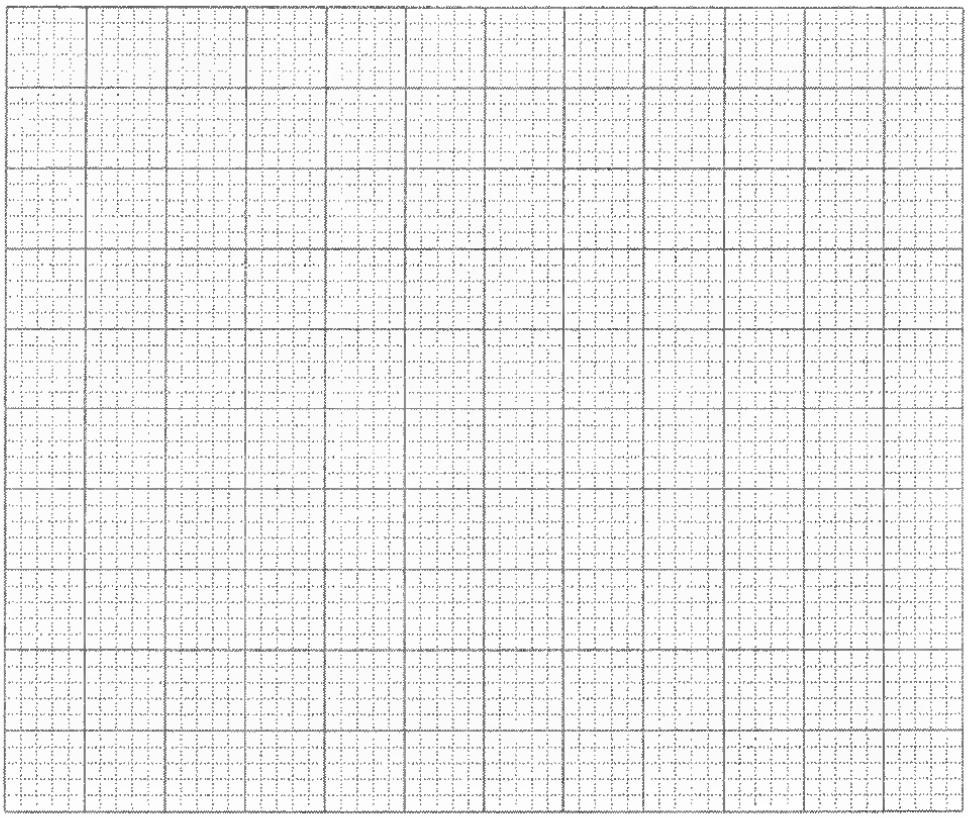
(ii) Two sources emitting the suitable type of radiation of half-lives 50 years and 10 hours are available. Which one should be used ? Explain briefly. (3 marks)

Q6. (93) In an experiment to measure the half-life of a radioactive isotope of sodium in a place where the background count rate is 100 counts per minute, the following result is obtained :

Time / hour	0	20	40	60	80	100	120
Total count rate/counts per min.	1100	498	259	161	125	110	104

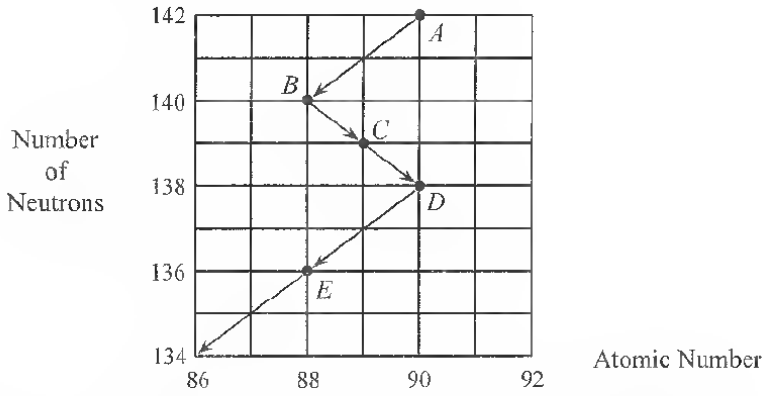
(a) Suggest TWO major sources of background radiation. (2 marks)

(b) Plot the graph of the CORRECTED count rate against time on graph paper. Hence find the half-life of the isotope. (6 marks)



(c) By considering its half-life, state whether the isotope is suitable to be used for injecting into a patient's vein so as to investigate his blood circulation. Give your reason. (3 marks)

Q7. The below figure shows part of a decay series.
(94)



(a) From the figure, name the particle which is emitted in each of the following changes :

(i) $A \rightarrow B$

(ii) $B \rightarrow C$ (2 marks)

(b) State two nuclides in the series which are isotopes of each other. (1 mark)

(c) The final stable nuclide of the series is X, whose atomic number is 82 and the number of neutrons is 126.

(i) Find the mass numbers of A and X. (2 marks)

(ii) Find the total number of α particles emitted from A to X. (2 marks)

(d) Some of the nuclides in the figure also emit γ-radiation when they decay. However, it is impossible to identify these nuclides from the figure. Explain briefly. (2 marks)

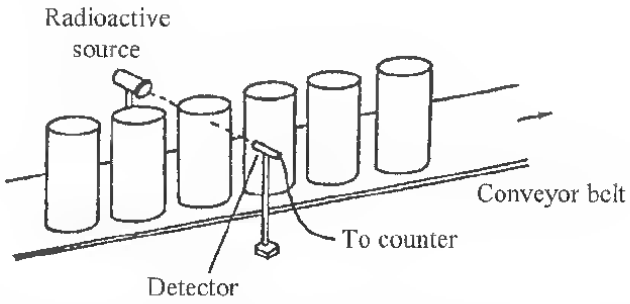
(e) A GM counter is placed 20 cm from a radioactive source which undergoes the decay as shown in the above figure. The corrected count rates obtained in three consecutive minutes are 1027, 1011 and 1018 counts per minute respectively.

(i) What type(s) of radiation emitted by the source can reach the counter ? Explain briefly. (2 marks)

(ii) Explain what is meant by a CORRECTED count rate. (2 marks)

(iii) Explain briefly why the three readings differ from each other. (2 marks)

Q8.
(96)



A factory produces detergent contained in plastic bottles. The following method is used to monitor the amount of detergent contained in each bottle : a radioactive source is placed on one side of the conveyor belt at the level to which the detergent is expected to fill and a detector is placed at the same level on the other side as shown in the figure above.

(a) Which type of radioactive source (α, β or γ) should be used ? Explain briefly why the other two types are not suitable. (3 marks)

(b) Suggest one suitable detector for the above system. (1 mark)

(c) Explain how the monitoring system can detect bottles of detergent that have not been filled up to the required level. (3 marks)

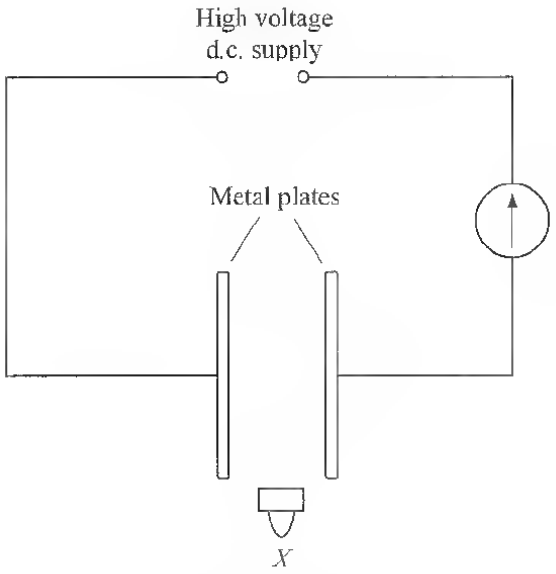
(d) Two sources emitting the suitable type of radiation of half-lives 10 minutes and 5 years are available.

(i) Explain what is meant by the half-life of a radioactive source. (2 marks)

(ii) Which source should be used ? Explain briefly. (3 marks)

(e) State two safety precautions that factory workers should take when handling radioactive sources. (2 marks)

Q9.
(97)



Two metal plates are connected to a high voltage d.c. supply and a galvanometer as shown in the Figure above. When a radioactive source X emitting α particles is placed very near the metal plates, the galvanometer shows that a current is flowing. When X is moved a small distance away from the two plates, the galvanometer reading quickly drops to zero.

(a) Explain why there is a current and why it is present only when X is very near the metal plates. (3 marks)

(b) $^{220}_{86}X$ decays by emitting an α particle to form a stable nucleus Y. Write down an equation for the decay. What is the neutron number of Y ? (3 marks)

(c) How would the galvanometer reading be affected if X is replaced by a β source ? Explain briefly. (2 marks)

Q9. (d) X is placed very near the metal plates and the galvanometer reading is recorded every 30 seconds. The results obtained are shown below :

Time / s	0	30	60	90	120	150
Current / μA	72	48	32	22	15	10

(i) Plot a graph of current against time on graph paper. (4 marks)

(ii) Hence find the half-life of X.

(Note : You may assume that the activity of the source is directly proportional to the current.) (1 mark)

(e) Explain why X is not suitable for use as tracers. (1 mark)

Q10. The radioactive isotope of sodium, $^{24}_{11}Na$, decays by emitting a β particle to form a stable isotope of magnesium (Mg). (98)

(a) Write down an equation for the decay. (2 marks)

(b) Suppose you are given the following apparatus :

a GM counter, a sheet of paper and a 5 mm thick aluminium sheet.

Describe how you can demonstrate that $^{24}_{11}Na$ emits β particles and does not emit α particles. (4 marks)

(c) The half-life of $^{24}_{11}Na$ is 15 hours. A sample of $^{24}_{11}Na$ with an activity of 32×10^3 disintegrations per second is injected into the blood stream of a patient. After 45 hours, 6 cm^3 of blood is taken out from the patient's body and its activity is found to be 5 disintegrations per second.

(i) How many half-lives of $^{24}_{11}Na$ will have elapsed after 45 hours ? (1 mark)

(ii) Estimate the volume of blood in the patient's body. (3 marks)

(iii) Suggest **two** reasons for using $^{24}_{11}Na$ in this dilution test. (2 marks)

(d) State an application of radioactive isotopes, other than tracers, in each of the following fields :

(i) Medicine (1 mark)

(ii) Industry (1 mark)

Q11. (a) (00) X and Y are two radioactive nuclides with half lives of 12 hours and 2.6 years respectively. Both two nuclides decay by emitting a β particle to form stable product nuclides.

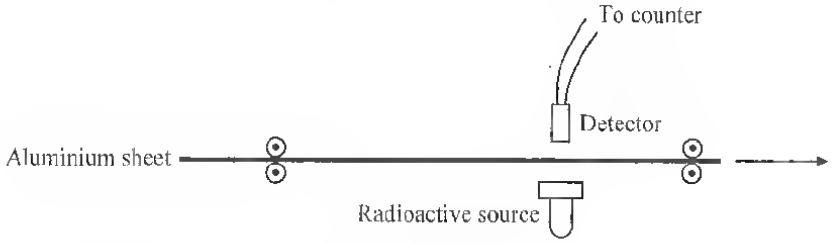
(i) After emitting a β particle, how would the atomic number and mass number of nuclide X be changed ? (2 marks)

(ii) Describe the changes in activity (in disintegrations per second) of a specimen of nuclide X and a specimen of Y after one day. (2 marks)

(iii) Comment on the following statement :

The mass of the specimen containing nuclide X will be reduced by approximately half in 12 hours. (2 marks)

(b) A factory produces aluminium sheets 1 mm in thickness. The thickness of the sheets is monitored by a gauge as shown in the figure below. A β source is used in the gauge.



(i) Explain why α and γ sources are not used in the gauge. (2 marks)

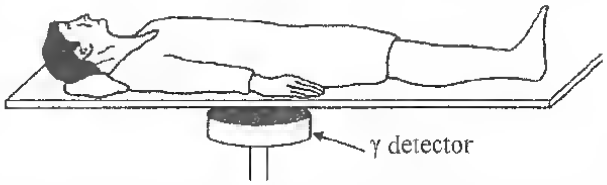
(ii) Which of the nuclides (X or Y) is more suitable to use as the radioactive source ? Explain your answer. (2 marks)

(iii) The count rate recorded should be around 90 counts per second when the thickness of the aluminium sheet is 1 mm. On a certain day when the gauge is operating properly, the following data are recorded :

Time / s	0	10	20	30	40	50	60	70	80	90	100
Recorded count rate / counts per s	90	89	91	90	90	88	66	64	90	89	89

Describe and explain the variation in the readings in the above table. (4 marks)

Q12.
(02)



Iodine-131 ($^{131}_{53}I$) is a radioisotope which decays by emitting a β-particle and γ rays. It is used in hospitals to test the kidneys of patients. During the test, an iodine-131 solution is injected into the bloodstream of a patient. As the blood passes through the kidney, iodine-131 will be absorbed by the kidney and eventually excreted out of the body with urine. If the kidney is not functioning properly, both the absorption and excretion rates of iodine-131 will decrease. A γ-detector is placed near the kidneys of the patient to detect the activity of the radiation coming from the kidneys as shown in the above figure.

(a) Using X to denote the daughter nucleus, write down an equation for the decay of an iodine-131 nucleus. (2 marks)

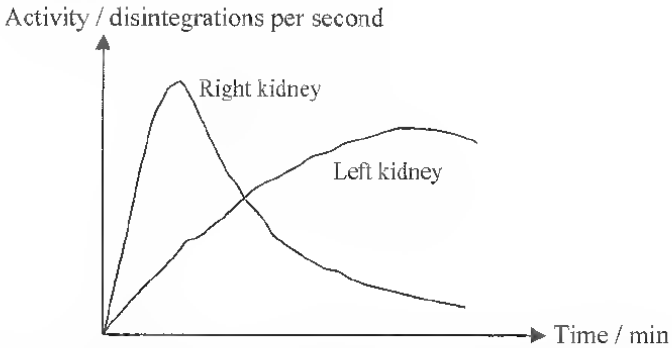
(b) Explain why the β-particles emitted by iodine-131 fail to reach the detector. (1 mark)

(c) The half-life of iodine-131 is 8 days.

(i) State the meaning of 'half-life'. (2 marks)

(ii) For safety purposes, the activity of iodine-131 solution in the test should not exceed 1.5×10^8 disintegrations per second. When an iodine-131 solution is prepared, its activity is 6×10^8 disintegrations per second. How many days after preparation would the solution be suitable for the test ? (2 marks)

(iii)



The above graph shows the variation of the activities of the radiation detected from the right and left kidneys of a patient with time. Which kidney do you think is not functioning properly ? Explain your answer. (3 marks)

(iv) Besides iodine-131, technetium-99m is another radioisotope that can be used in the kidney test. Technetium-99m emits γ radiation only and its half-life is 6 hours. Which of these two sources do you think is more preferable for use in the kidney test ? Explain your answer. (4 marks)

Q13.
(04)

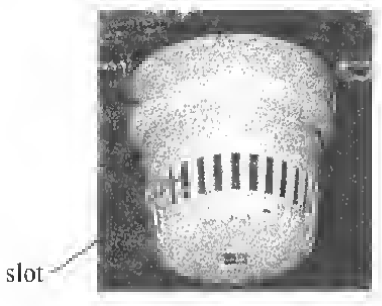


Figure 1

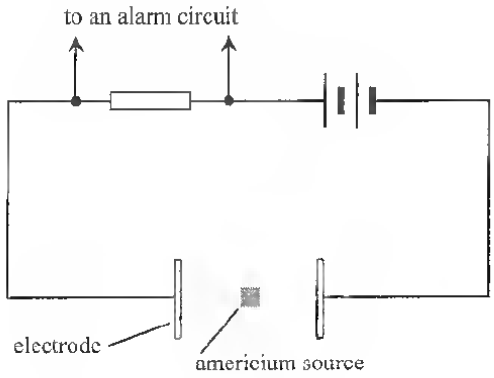


Figure 2

Figure 1 shows a smoke detector. The circuit inside the detector is shown in Figure 2. A small amount of the radioisotope americium-241 ($^{241}_{95}\mathrm{Am}$) is placed between two electrodes. The two electrodes are connected to a battery and an alarm circuit. The detector has slots in it to allow air flow.

(a) An americium-241 nucleus decays by emitting an α-particle to form a daughter nucleus neptunium (Np), with a half-life of 432 years.

(i) Write down an equation for the decay of an americium-241 nucleus. (2 marks)

(ii) Find the number of neutrons in the daughter nucleus. (1 mark)

(b) Under normal conditions, a small current flows in the circuit inside the detector. However, when smoke particles enter the detector, the current drops significantly. This triggers the alarm to sound.

(i) Explain why a current flows between the electrodes under normal conditions. (3 marks)

(ii) Suggest one possible reason why the current drops when smoke particles enter the detector. (2 marks)

(c) Explain why it is preferable for the radioactive source used in smoke detectors to have a long half-life. (2 marks)

(d) Carbon-14 ($^{14}_{6}\mathrm{C}$) is a radioisotope which decays by emitting β particles and has a half-life of 5700 years. Explain whether this source is suitable for use in smoke detectors or not. (2 marks)

(e) People are concerned about the biological hazards of radiation. If you are the manufacturer of the above described smoke detector, how would you explain to the public that using the detector will not pose any health hazard ? (2 marks)

Q14. Read the following passage about Iodine-131 therapy and answer the questions that follow.
(05)

Iodine-131 is a radioisotope which emits β and γ radiation. It can be used for thyroid cancer treatment.

A patient suffering from thyroid cancer will first undergo an operation to have the thyroid gland removed. However, some thyroid tissue may remain in the neck of the patient or may be carried in the blood stream to other parts of the body. Iodine-131 is then used to trace and get rid of the remaining thyroid tissue in the body.

Iodine-131 therapy consists of two stages. In Stage 1, the patient will take a low dose of Iodine-131 to trace the remaining thyroid tissue. A detector is placed near the patient to monitor the activity of the radiation coming from the patient.

In case any remaining thyroid tissue is spotted in Stage 1, the patient will then take a higher dose of Iodine-131 in Stage 2. The iodine will be absorbed by the thyroid tissue and the radiation emitted can kill the cancer cells.

Special hospital rooms are designed for patients who receive Stage 2 of the therapy. The rooms have metallic shielding in the doors and reinforced walls. Inside the rooms, there are plastic covers on the furniture, doors, handles and switches.

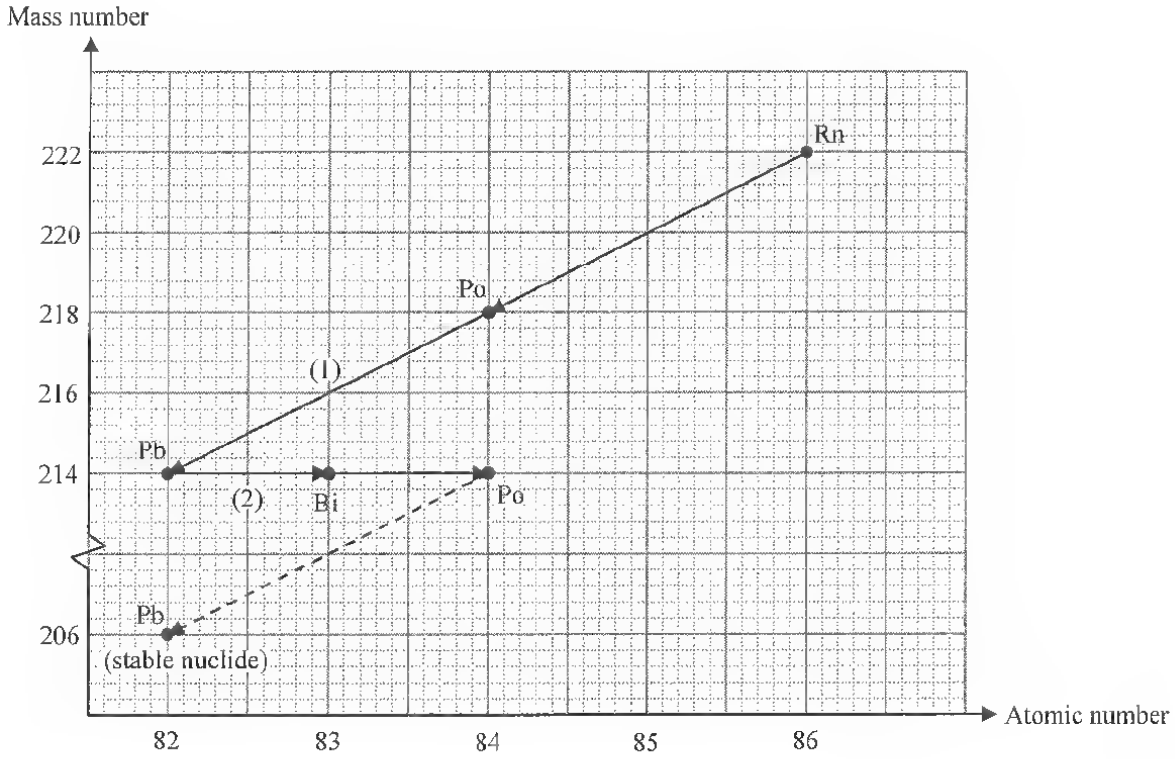
Source : *Iodine-131 Therapy*, The Ohio State University Medical Center, 2003.

(a) Explain why, in Stage 1, β radiation from the patient cannot be detected by the detector. (1 mark)

(b) In Stage 2, which kind of radiation is more effective in killing cancer cells ? Explain your answer. (2 marks)

(c) State one special feature of the hospital rooms designed for patients receiving Stage 2 of the therapy and explain its function. (2 marks)

Q15. Radon-222 (Rn-222) has a half-life of 3.8 days and undergoes a radioactive decay series as shown in the Figure below to become a stable nuclide Lead-206 (Pb-206). (09)



(a) Estimate the mass of undecayed Rn-222 after 15.2 days if its initial mass is 1×10^{-5} g. (2 marks)

(b) State the nuclear radiation emitted in process (1) indicated in the above Figure. (1 mark)

(c) Write down a nuclear equation for process (2) indicated in the above Figure. (2 marks)

(d) Determine the total number of α particles and the total number of β particles emitted in the radioactive decay series from Rn-222 to Pb-206. (4 marks)

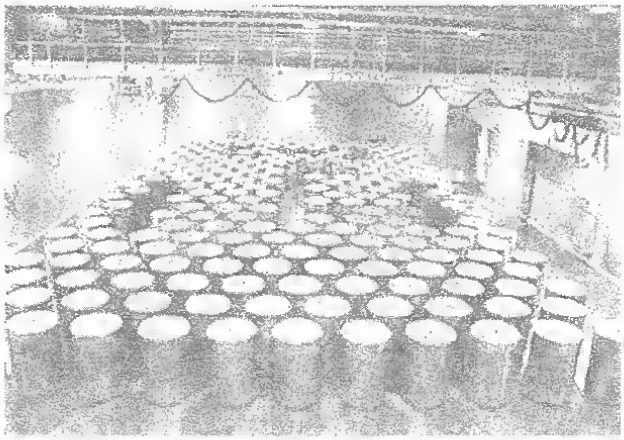
Q16. Read the following passage about low-level radioactive waste and answer the questions that follow. (10)

Low-level Radioactive Waste

Industrial, medical and educational institutions in Hong Kong generate small amounts of low-level radioactive waste. Such waste produces no detectable heat output and is of low radioactive level. Weakened radiation sources from hospitals and educational institutions are examples of low-level radioactive waste.

For many years, most of the waste had been stored in disused tunnels and hospitals. The Government considers that in the long run the low-level radioactive waste should be stored in a purpose-built facility. After about two years of construction, the Low-level Radioactive Waste Storage Facility (the Facility) (see the Figure below) at Siu A Chau, an uninhabited island to the southwest of Lantau Island, was successfully commissioned and began its operation in July 2005. It comprises a shielded waste storage vault, a fully equipped laboratory, an automatic control room, an advanced wastewater treatment plant and specially designed waste reception and processing area. The radiation levels inside and outside the Facility are continuously monitored to ensure safe operation.

The Low-level Radioactive Waste Storage Facility at Siu A Chau - Storage Vault



(a) State one characteristic of low-level radioactive waste. (1 mark)

(b) Explain why Siu A Chau is suitable for the storage of low-level radioactive waste. (1 mark)

(c) Suggest an instrument to monitor the radiation levels inside and outside the Facility. (1 mark)

(d) In hospitals, radioactive sources are used as tracers. The radioactive source is injected into a patient's body and the radiation level is monitored with detectors outside the body. Explain why γ source is suitable for using as tracers. (2 marks)

Q17. (10) Carbon-14 dating can be used to identify the age of some objects. Living organisms contain a constant proportion of carbon-14. After an organism dies, the amount of carbon-14 in it decreases due to decays. We can estimate the age of an object by measuring the activity of carbon it contains.

(a) Carbon-14 undergoes decay as shown in the following nuclear equation, where D denotes the daughter nucleus.

$$^{14}_{6}C \rightarrow {}^{y}_{x}D + \beta$$

Find the values of x and y. (2 marks)

(b) In a piece of wood found, the activity of 10 g of carbon is 35 disintegrations per minute. It is known that the activity due to 10 g of carbon in a living plant is 140 disintegrations per minute. Estimate the age of this piece of wood. Given that the half-life of carbon-14 is 5700 years. (3 marks)

Q18. (11) It is known that plutonium-238 ($^{238}_{94}Pu$) decays by emitting one α particle.

(a) Write a nuclear equation for the decay of plutonium-238. Use the symbol Y as the daughter nucleus. (2 marks)

(b) A sample of plutonium-238 is put in a cloud chamber. Some tracks are seen.

(i) Describe the tracks that are seen. (1 mark)

(ii) No tracks can be seen when the sample is covered by a piece of paper. Explain. (2 marks)

(c) Plutonium-238 can be used in heater units in spacecrafts for outer space missions. It is known that the power of the heater unit is directly proportional to the activity of plutonium-238 contained. Each heater unit has a power of 2 W when it is newly manufactured. How long can a newly manufactured heater unit last if the minimum power output required is 0.25 W ?

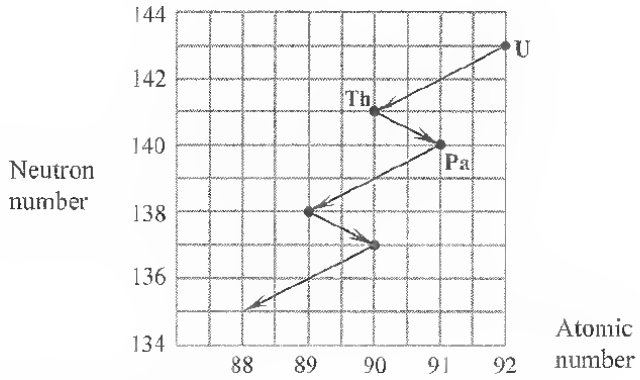
Given : half-life of plutonium-238 = 87.7 years (3 marks)

Part C :

The following questions marked with [ ] are the past HKAL questions.

The number inside the brackets represents the year of the examination.

Q19. The figure below shows the decay series for $^{235}_{92}U$.
[93]



(a) Name the particles emitted when

(i) Uranium (U) decays to Thorium (Th); and (1 mark)

(ii) Thorium (Th) decays to Protactinium (Pa). (1 mark)

(b) Given that the half-life of $^{235}_{92}U$ is 7.1×10^8 years, what would be the percentage of $^{235}_{92}U$ left after a period of 10^8 years ? (3 marks)

Q20. Carbon-14 dating is used to determine the age of archaeological sample by measuring its activity due to the carbon-14 [09] remaining in it.

(Given : mass of one mole of carbon-12 = 12.0 g and half-life of carbon-14 $t_{1/2}$ = 5730 years)

(a) (i) Calculate the decay constant k, in s^{-1}, of carbon-14. (2 marks)

(ii) It is known that the relative abundance of carbon-14 in living things is that there is only one carbon-14 atom for every 7.2×10^{11} atoms of carbon-12. Calculate the activity for 1 g of carbon in living things. (3 marks)

Q20. (b) (i) Explain the origin of carbon-14 in the atmosphere and why the abundance of carbon-14 in living things, such as plants, remains more or less constant. (3 marks)

(ii) After corrected for background radiation, an archaeologist measured an activity of 20 disintegrations per minute from 10 g of carbon in a piece of bone. Use the result in (a) to estimate the age of the bone. (3 marks)